THE MARINE ANNELIDES OF THE ORDER *SERPULEA*. SOME OBSERVATIONS ON THEIR ANATOMY, WITH THE CHARACTERISTICS OF THE AUSTRALIAN SPECIES.

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[Plates XXXI. to XXXV.]

In the following paper are given the results of some observations and researches which I have made during the last few months on the *Serpulea* of Port Jackson. The number of species which I have made the subject of investigation is limited; but it comprises representatives of all the principal sub-divisions of the group. These differ very little from their European allies, and there is nothing specially to characterise the Australian members of the order so far as I have had the opportunity of investigating them. To the notes on the species which I have myself examined I have added the descriptions of others previously described by other writers as found on the Australian Coast.

The researches of Claparède (1) on the minute structure of the sedentary Annelides have left but little to be done by his successors, and I find that the results of a considerable amount of work comprise but few facts which were not previously observed and illustrated by the Genevese *savant*. There are, however, two subjects in which I think I have been enabled to add to our knowledge of the group, and to those I have mainly confined myself in the following notes on the anatomy.

(1) "Recherches sur la Structure des Annélides Sédentaires," Geneva, 1873; "Annélides Chétopodes du Golfe de Naples," Genève et Bâle, 1868, with Supplement, 1870; "Glanures Zootomiques parmi les Annélides de Port Vendres," 1868; "Beobachtungen über Anatomie und Entwickelungsgeschichte wirbelloser Thiere."

The methods of preparation which I have employed are mainly the following:—For dissociation of elements, such as muscular fibres or epithelial cells, I have used immersion in weak alcohol (90% alcohol 1 part, water 2 parts) for two or three days; followed by picrocarmine and Farrant's solution. For hardening I have found the corrosive sublimate and alcohol method preferable to any other. The most perfect stain for the general histology of the tissues is effected by an absolute alcohol solution of eosin, followed by Kleinenberg's hæmatoxylin, both dyes being used very dilute and the process being extended over four or five days. The chloroform-paraffin method of Giesbrecht (1), though a little tedious, is preferable to any other method of embedding for the present group as for most others, and particularly so when employed in conjunction with Caldwell's invaluable ribbon method of cutting sections with the automatic microtome. The series are best fastened to the slide with a weak solution of gum arabic (2), and the paraffin removed with benzol, which should be followed by oil of cloves and Canada balsam dissolved in chloroform. In cases in which sections prepared as above show, on examination before final mounting in balsam, that some part which may be specially required is not adequately stained, the following fluid will be found useful,—

Saturated solution of hæmatoxylin in absolute alcohol, 100 c.c.

Oil of cloves 100 c.c.

Saturated solution of alum in water, 2 c.c.

This fluid mixes with the benzol and does not cause solution of the gum arabic; its action, owing to its clarifying effect on the tissues, can be watched with great ease. It should be removed and replaced by oil of cloves before balsam is added, as, should any of it be allowed to mix with the balsam, a process of slow staining will still go on after the sections are mounted.

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(1) "Zur Schneide Technik," Zool. Anz., 1881, No. 92.

(2) J. H. L. Flögel, Zool. Anz. VI., 565.

PSEUDOHÆMAL SYSTEM.

The vascular system of the *Serpulea* has been treated of by several anatomists—among the number Williams (1), Milne-Edwards (2), Grube (3), Quatrefages (4), and Clarparède (5.) The most detailed account of the course of the circulation is given by the last-named author, who studied it chiefly in *Spirographis Spallanzanii*, but ascertained that the same general arrangement holds good in the *Serpulidæ*. The leading peculiarity of the pseudohæmal system of this family, as of the Sabellidæ, the Ammocharidæ, the Ariciidæ and the Chætopteridæ, consists in the presence of a peri-intestinal vessel or sinus excavated in the muscular wall of the alimentary canal, and extending from the hinder extremity of the body as far as forwards as the œsophagus and stomach. This peri-intestinal sinus takes the place of the dorsal vessel found in other Annelids. It terminates in front, according to Claparède, by breaking up into a network of small vessels, which again further forward are gathered up into several larger trunks, the two most important of these being the branchial vessels. Throughout the greater length of the body the peri-intestinal sinus is accompanied on the ventral side by a ventral vessel. This gives off a pair of branches in each segment, and ends in the thoracic region by breaking up into smaller vessels, which join the capillary plexus.

"Le mode de circulation chez les Sabelliens devient compréhensible par la description qui précède. Les ondes de contraction du sinus intestinal chassent le sang d'arrière en avant, comme il est facile de s'en assurer sur le vivant. Ce sang remplit le plexus œsophagien, et les deux vaisseaux branchiaux ont des parois contractiles grâce à un développement musculaire remarquable. Une onde de contraction, parcourant d'arrière en avant les vaisseaux branchiaux, chasse le sang jusqu'aux dernières

(1) British Association Report, 1851, p. 187.
(2) "Recherches pour servir à l'histoire de la circulation du sang chez les Annélides" Ann. Sci. Nat. 2me. sèr. X., p. 193.
(3) "Anatomie der Kiemenwürmer."
(4) "Histoire Naturelle des Annélés marins et d'eau douce."
(5) "Recherches sur la structure des Annélides sédentaires."

extremités des rayons branchiaux et vide en grande partie les deux troncs principaux; puis une onde de contraction en sens contraire ramène le sang dans le plexus. Là, le sang oxygéné se mèlange avec le sang veineux, le plexus étant un réservoir commun. Il s'engage dans tous les vaisseaux qui naissent du plexus, en particulier, dans le vaisseau ventral qui le porte en arrière jusqu' à l'extremité du corps. On doit remarquer que le jeu alternatif du plexus à la périphérie et de la périphérie au plexus, n'existe pas seulement pour les vaisseaux branchiaux, mais encore pour tous les vaisseaux qui naissent en dessus du plexus. C'est le cas en particulier pour le grand tronc vasculaire de la collarette, tronc unique de chaque côté" (1.)

It is somewhat remarkable that prior to the time of the publication by Claparède of his "Recherches sur la structure des Annélides Sédentaires," the existence of a dorsal vessel was almost invariably postulated by those who studied the pseudohæmal system of the Serpulea. Thus Milne-Edwards (2) in describing the vessels of *Sabella* states. "On y trouve un vaisseau dorsal très grêle accolé au tube digestif et reçevant au niveau de chaque cloison interannulaire une paire de branches transversales qui viennent des parties laterales du corps."

To M. A. de Quatrefages (3) is due the credit of having first called attention to the existence of a peri-intestinal vessel or sinus; though Grube had already remarked on the absence of a dorsal-vessel proper. The account which the former author gives of the course of the circulation is quoted by Claparède (4), as showing that he was not aware of the absence of a dorsal vessel; but his words may, I think, very well bear a different interpretation. They are—"Chez les Sabelliens, les Terébelliens, les Chlorémiens, *on voit* le sang ariver d'arrère en avant jusqu' à la base des branchies par le grand tronc supérieur, remplir l 'espèce de sinus

(1) L. c., p. 81.
(2) "Recherches pour servir à l' histoire de la circulation du sang chez les Annelides," Ann. des Sc. Nat. 2e série, t X., pp. 129 et seq.
(3) Histoire Naturelle des Annélés, tome II., p. 406.
(4) l. c., p. 78.

qui s'y trouve; pénétrer dans l'organe respiratoire, en sortir et suivre une marche inverse d'avant en arrière par le tronc inférieur." Here the "grand tronc supérieur" must be the peri-intestinal sinus, not the dorsal vessel, and the view of the course of the blood is, on the whole, correct.

In some of the species in which I have specially studied the circulation, the arrangement is somewhat different from that described by Claparède as obtaining in Spirographis, so that there would seem to be considerable variation in this respect even within the limits of a single family.

In all the intestine is surrounded throughout the greater part of its length by a peri-intestinal sinus which gives off numerous branches to the segments. In *Eupomatus elegans*, this sinus ends in front in the œsophageal region of the body and opens into a short wide dorsal sinus or cardiac sac (pl. XXXI., fig. 2, *d. s.* and fig. 3, *h. t.*); passing off from this in front are a pair of trunks (fig. 2, *d. b. v.*) which run forwards and outwards for a short distance to the base of the branchiae where each unites with a similar branch from the ventral vessel to form the common branchial vessel (*c. b. v.*) of the right or the left side as the case may be. The latter runs in an arched manner along the bases of the branchiæ giving off a single branch to each of them, and one to the operculum and the pseud-operculum. The ventral vessel (fig. 1, *a*; fig. 2, *v. v.*) is a distinct wide trunk which is continued along the whole length of the body beneath the peri-intestinal sinus; in front it bifurcates, each of the branches presenting a contractile dilatation (fig. 2, *v'. v'.*) at its base, and in front communicating with the branches from the dorsal sinus to form the common branchial vessels as above described. The rich network of capillaries in the collarette and lateral flaps receives its blood from the ventral vessel, and the circulation is here, as in the branchiae, a to-and-fro one, the same vessels acting both as afferent and efferent trunks for the capillary networks.

The course of the blood in *Eupomatus* is as follows:—

The blood which enters the peri-intestinal sinus by the segmental vessels is carried forward by peristaltic contractions to

the cardiac sac; from this it is driven at intervals forwards to the common branchial vessels, from which it passes by the vessels of the branchial stems to the extremity of the branchiae; returning by the same course it enters the lateral ventral trunks and passes thus to the ventral vessel by which it is distributed to the capillary networks of the collarette and lateral flaps and to the body generally. That all the blood constantly and regularly takes this course is not to be supposed; the absence of valves, the constant and irregular contractions of the body of the worm interfere with any such regularity; but the above may be taken as an accurate general account of the course of the circulation in this species.

In *Pomatoceros* the arrangement of the vessels is much more like that described by Claparède as occurring in *Spirographis*. In the abdominal region the principal trunks are the peri-intestinal vessel, an exceedingly minute ventral vessel, situated between the widely separated nerve cords, and several other trunks, mostly longitudinal in direction, which lie in the peri-intestinal space and are covered by a layer of granular cells. In the front of the thoracic region (pl. XXXV., fig. 2) the peri-intestinal vessel becomes divided into a large dorsal vessel or cardiac sac (*d. v.*), and a series of about sixteen smaller vessels (*l. v.*), which run along the wall of the alimentary canal. The ventral vessel still retains its position. A little further forward the peri-intestinal vessels join the dorsal trunk, so that we have here two main vessels, a large dorsal and a very small ventral. Very soon the dorsal vessel bifurcates into two branchial vessels. The ventral vessel also bifurcates anteriorly; but whether the two ventral trunks thus formed communicate in front with the dorsal branchial vessels as in *Eupomatus* I am uncertain: it seems probable that they do, as they are traceable into the base of the lophophore.

All the vessels, as observed by Claparède, possess a muscular wall; in the smaller vessels this is only to be detected by the presence at intervals of fusiform nuclei; but in the larger trunks the layer is more distinctly developed. In the structure of the

vessels the only remarkable point I have noticed is the great development in the dorsal, opercular, and branchial trunks of *Vermilia* of a relatively very thick layer of circularly arranged muscle with a few elastic fibres. A similar coat has been detected in the principal vessels of several other Annelids, s. g. *Phreoryctes*.

The blood in most of the species of *Serpulidæ* which I have examined is a light green colour. Under the action of alcohol it coagulates to form a clear clot which stains very readily with hæmatoxylin or carmine. Within the lumen of all the vessels, but usually close to the periphery, are to be observed a number of clear oval bodies (pl. XXXIV., fig. 5, *a.a.*, *b.b.*) usually of $\frac{1}{7500}$th of an inch in diameter, though smaller ones are to be observed here and there. These bodies never become stained under the action of any staining fluid more intensely than the coagulum of the blood by which they are surrounded. They may be seen to lie free in the cavity of the vessel in the living animal and to move with the motion of the blood, but examination of a number of sections will show now and again one of these bodies connected with the wall of the vessel by a narrow neck which is continuous with the clear substance of the body itself. Corpuscles have been already detected in the pseudohæmal system of several genera of Annelides (1), and doubtless such of the bodies above described as lie free in the cavity of the vessel are of this nature. The occurrence, here and there, of corpuscles connected with the wall of the vessel would seem to point to the derivation of the free corpuscles from the endothelium.

SEGMENTAL ORGANS AND "TUBIPAROUS GLANDS."

The pair of large and conspicuous glands found in the anterior part of the body in the members of this group, have been set down by Claparède as the only equivalents of the "segmental

(1) J. E. Blomfield and A. G. Bourne, Q. J. Micr. Sci. XXI (1881), pp., 500-501; Mau, "Ueber Scoloplos armiger," Zeitschr für Wiss. Zool., XXXVI., p. 389, Rolleston, "Blood Corpuscles of the Annelides," Jour. Anat. Phys. XII., p. 401-419.

organs" of other Annelides (1), and he regards excretory ducts for the generative products as being entirely absent,—the ova and spermatozoa escaping either by rupture or through simple apertures in the body wall (2).

The true "segmental organs," however, which seem hitherto to have escaped notice, are entirely distinct from these large "glandes tubipares," or "organes segmentaires" of Claparède. They are found in pairs in all the segments of the abdomen. They consist of pyriform sacs (pl. XXXIV., fig. 6), densely ciliated internally and with very delicate colourless walls. These sacs open externally on the sides of the segments by slit-like apertures bordered by strong cilia, and, presumably, open also internally into the body cavity, though I have not succeeded in finding the internal opening. A somewhat unusual circumstance in connection with these organs is that, in *Eupomatus elegans* at least, they serve not only as efferent ducts for the generative products, but also as seats of development of the ova. In that species I found *in the cavity of each segmental organ* a little clump of ova in all stages of development, from the transparent immature cell to the perfectly developed ovum, with its granular interior and characteristic reddish pigment. The little group of ova in the interior of each segmental organ were closely adherent together, and rotated round and round under the action of the cilia. Alternating with the segmental organs were the true ovaries consisting of clumps of ova in various stages of development and occupying the ordinary position. In the male specimens examined I have always found the sacs empty.

These segmental organs of *Eupomatus* are of an extremely simple type; but organs of equal simplicity are known to occur in other forms, *e. g. Scoloplos* (3.) The discovery of the ova in their interior places their function beyond a doubt, though at the same time from the mode of their occurrence as a free group of

(1) L.c., p. 132.
(2) "Il est certain qu'il ne se presente nul part chez les Serpuliens d'organes segmentaires de la forme typique," l c, p. 135.
(3.) Mau, Zeitscrift für Wiss. Zool. Band XXXVI., p. 389,

ova in various stages, adding an element of perplexity. It would seem to afford additional evidence in favour of the theory that the ova may be developed from the corpuscles of the perivisceral fluid.

The so-called tubiparous glands were noticed by Huxley in *Protula Dysteri*. They were described by Quatrefages, curiously enough, as hepatic cæca, similar in their relations to the hepatic cæca of the Aphroditea (1.) They were examined more minutely by Clarparède, by whom, as above noticed, they were regarded as the sole equivalents in this family of the segmental organs. Clarparède directs attention to a great difference which he considers to exist in their disposition in the Sabellidæ and in the Serpulidæ. In the former family, he states, each "tubiparous gland" has the form of a tube bent on itself, the two branches being cemented together. These two branches are of very unequal dimensions; the narrower, which is also internal, opening into the perivisceral cavity; the other enlarges into a wide sac which gradually becomes narrowed to form the excretory duct, opening at the base of the first parapodium. In the *Serpulidæ*, on the other hand the tubiparous glands of opposite sides unite to form a common mesial excretory duct which opens in front between the bases of the branchiæ (2.)

I have only examined the tubiparous gland in one species of the Sabellidæ, a species of *Sabella*, and I find that, so far from according with Claparède's description, the gland has exactly the relations which it has in the Serpulidæ. The common duct opens in the usual situation; it early bifurcates, the two branches running close to one another for a short distance. In this situation the efferent ducts are lined by an epithelium which consists of extremely low flat cells with granular contents and with long flagella.

Within the limits of the family Serpulidæ itself I have found considerable variations in the form and structure of these organs. The simplest form is presented by *Eupomatus*, and in *Serpula* the arrangement is closely similar. In these genera each gland

(1) Hist. N. des Annélés, t. I., p. 49.
(2) l.c., p. 133.

(pl. XXXI., fig. 1, *n.*, and pl. XXXIV., fig. 7) presents the form of a somewhat oval brown body situated in the anterior region of thorax and having its long axis directed nearly longitudinally. In this body two parts are distinguishable, a posterior with thinner and clearer walls, and an anterior dark brown and having the walls somewhat folded. I can find no trace of any opening into the perivisceral cavity. In front the gland is continued into the duct, which passes almost directly inwards to meet with its fellow in the middle line. The delicate common duct (*a.*) into which the gland-ducts of opposite sides unite passes straight forwards to open towards the ventral side of the anterior end of the body, between the bases of the branchiae. Each lateral duct is ciliated and its epithelial lining is granular; while I have been unable to find any trace of cilia in the common duct and its epithelium is free from conspicuous granules. The gland itself (pl. XXXIV., figs. 8 & 9) is lined with a layer of very remarkable cells. They are very large, densely granular cells of a form which may be described as that of a cone with an obtuse apex and a polygonal base. The polygonal bases of contiguous cells fit in together so as to form a continuous lining for the sac of the gland; while the apices project freely into the lumen. Each cell possesses a large spherical nucleus situated near the base. The truncate apex of each cell is provided with a leash of extremely long and flamentous cilia or rather flagella, often four or five times the length of the cells themselves, and often much longer than the breadth of the cavity of the sac. In certain positions groups of the cells are elongated so as to form a prominent ridge projecting into the cavity. A very thin fibrous coat invests the gland.

In *Vermilia* the duct is wider than in *Eupomatus*, and dilates before it opens into the gland, which is divided into four parts. The latter are long and wide thin-walled sacs, the inner pair approaching one another in the middle line and encircling about a half of the retractor muscle of the branchiæ; the outer placed close to and connected with the body-wall at some distance from one another on the ventral aspect. The inner pair extend further back than the outer.

The wall of the duct is lined by a granular ciliated epithelium. The walls of the gland have an epithelium similar to that already described in the case of *Eupomatus*, with highly granular cells and long cilia; but the cells are very much smaller, being only about $\frac{1}{2500}$th of an inch in long diameter, and the cilia are not so numerous and much more delicate. The epithelium of the outer sac is much thicker and more densely granular than that of the inner; it is richly supplied with pseudohæmal vessels. At intervals among the granular cells lining the sac occur others which are transparent and free from granules. Here and there among the granular cells are opaque mulberry-like or spherical concretions, which are seen on a close examination to be made up of agglomerations of granules.

In *Pomatoceros*, (pl. XXXV., fig. 2, t.g., fig. 3, and fig. 4), as in the other genera, the common excretory duct of the glands opens upon the anterior and ventral aspect of the head between the bases of the branchiæ; it runs backwards along the ventral side of the depression separating the præstomial lobe from the lips of the alimentary canal, forming a conspicuous ridge. In this situation its wall is formed (1st) of a continuation of the cuticle of the surface of the head (2nd), a layer of hypoderm which differs from that around in being composed of short columnar cells (3rd), a layer of fine connective tissue with perhaps muscular fibres, and (4th), the epithelium, which is composed of cubical or polyhedral cells filled with brown granules. In the connective tissue layer are a few pseudohæmal vessels. A little further back the common duct bifurcates, the two branches each forming almost a right angle with it, and each opening into the gland of its side. Each gland consists of a single elongated sac occupying a lateral position close to the body-wall. I can find no opening into the perivisceral cavity. The walls of this sac are much folded and are of considerable thickness and great opacity. They are formed, besides an outer connective and muscular coating with numerous pseudohæmal vessels, of a very thick and dense layer of elongated cylindrical epithelial cells (fig. 4) densely packed with yellowish-brown granules. These cells are much smaller

and relatively narrower than the corresponding cells in *Eupomatus*, and are more densely granular; they resemble these, however, in having at their internal extremity a clear conical projection or papilla from which arise one or several long flagelliform cilia. The nuclei, which are rather small, are situated nearer the proximal than the distal end of the cell, and there are no additional nuclei about their bases, the cells constituting a single layer without the "*cellules de remplacement*" found in the hypoderm.

In *Sabella velata* the glands have a low epithelium somewhat similar to those of *Vermilia*, and are deeply lobed posteriorly. In the hinder part of the thorax is a second pair of lobed glands with granular cubical ciliated epithelium, situated on either side between the nerve-cords and the alimentary canal. These disappear in front a little distance behind the posterior termination of the anterior pair of glands, and I have been unable to determine their relations to the latter.

AUSTRALIAN SPECIES.

Eupomatus elegans, Mihi. (1)

[Pl. XXXI., figs. 3 and 4; pl. XXXII., figs. 11 and 12; and pl. XXXIII., figs. 1-6.]

This species is to be found in great abundance adhering to the stems and fronds of certain sea-weeds at a depth of 10 or 12 fathoms in Port Jackson. I have also found it, though very rarely, adhering to the under surface of large blocks of stone a little below low-water mark. The relationship between it and its European congener is extremely close, and with such a variable species it is very difficult to be quite clear as to their distinctions. The probabilities, however, are all in favour of a separation, and doubtless a comparison of a series of each would show certain prevalent distinctive characteristics. Meanwhile I retain the name given when I had only seen a few specimens.

(1) Proc. Linn. Soc., N.S.W. Vol. VII., p. 633.

The tube assumes a variety of shapes according to the form of the object to which it is adherent; it is always thin-walled, with slight, irregularly placed, ring-like thickenings; in transverse section it is almost perfectly circular. The proximal portion of the tube, which is usually the part which is adherent, is very slender, and nearly always much curved and may be coiled into a short spiral. The diameter increases distally till at the mouth it is about $\frac{1}{10}$th of an inch. The free part of the tube is only very gently sinuous. The total length may be as much as an inch and a half, but is usually less.

The ordinary length of the annelid is about half an inch. The thorax, which is considerably shorter than the rest of the body, contains seven segments; it bears very wide lateral flaps and prominent parapodia with long setæ. The setæ of the first segment (pl. XXXIII., figs. 4 and 5) differ from the rest (pl. XXXIII., fig. 6.)

The ventral tori are ·0075 to ·0150 of an inch in length, each is composed of about twenty to thirty-five pectines, about ·001 inch in length and having six or sometimes seven teeth (pl. XXXIII., fig. 3.) The abdomen contains forty to forty-five segments with long setæ, and ends in a pair of short rounded anal processes.

The branchiæ (pl. XXXI., fig. 4), which are twenty in number, have long slender stems beautifully ornamented with lines of white, crimson, red and brown, the arrangement of which is subject to great variation. The operculum (pl. XXXII., figs. 11 and 12 and pl. XXXIII., figs. 1 and 2) has a very long and slender cylindrical stem reaching far beyond the extremity of the branchiæ and more than half the length of the whole body. It is uniform in diameter to near the base of the operculum, where it gradually enlarges to form the basal portion of the latter. The operculum is composed of two segments the proximal formed by the expansion of the extremity of the peduncle to form a wine-glass-shaped body the rim of which is divided into lobes or teeth. The number and size of these lobes or teeth varies to some extent according to the age of the specimen or of the operculum. In young opercula

they are few and large; as growth proceeds they become more numerous and smaller, the additional lobes being apparently formed by the longitudinal division of the original broad ones as is shewn by two of them being frequently united below. The lobes themselves are frequently, though not always, armed with minute denticles or spinules, a pair on each. Into the hollow of the cup formed by the proximal portion of the operculum fits the distal part, which is also wine-glass-shaped, with the neck attached to the centre of the proximal segment, and the rim also divided into a series of teeth. These distal teeth are much longer than the proximal set, and taper to a fine point laterally and internally each bears seven or eight acute spines. In number they vary from thirteen to twenty. In the centre of the concavity of this distal segment of the operculum is frequently a strong spine like the teeth of the distal circlet and armed with spinules. Usually only one operculum is developed and this may be either the right or the left. Not unfrequently, however, both opercula are equally developed. When only one operculum is fully developed the other is represented by a club-like process containing a pseudohæmal vessel.

2. Cymospira brachycera.

Cymospira brachycera, Baird, "On some new species of Tubicolous Annelids in the collection of the British Museum," Journ. Linn. Soc. Zool., Vol. VIII., p. 17, pl. II., fig. 2.

"Branchiæ in spiras quinque convolutæ. Operculum magnum, cornibus duobus brevissimis irregulariter dentatis armatum." (Baird.)

"East Coast of Australia." [Brit. Mus.]

3. Cymospira Mörchii.

Cymospira Mörchii, Quatrefages, l.c., pp. 540 and 541.

"Caput indistinctum. Branchiæ cirris numerosis in basi vix quadrispirali. Operculum tricorne. Collare trilobum. Corpus 100 annulis circiter compositum, anterioribus 7. Setæ anteriores late limbatæ. Pro uncinis laminæ læves." (Quatrefages.)

I have not seen this species. The locality given by Quatrefages is "New Holland."

4. Pomatostegus Bowerbanki.

Pomatostegus Bowerbanki, Baird. Journ. Linn. Soc. Zool., Vol. VIII., p. 20, pl. II., figs. 4 and 5.

"Branchiæ curtæ, in spiram unam et dimidiam convolutæ. Opercula quatuor, versus apicem decrescentia, inarmata." (Baird.)

"Seas of Australia. [Brit. Mus.]

5. Pomatoceros elaphus.

[Plate XXXI., fig. 7 and Plate XXXII., figs. 9 and 10.]

? *Pomatoceros tetraceros*, Schmarda, Neue Wirbellose Thiere, I., II., p. 30, pl. XXI., fig. 129.

? *Vermilia tetraceros*, Quatrefages, tom. cit. II., p. 520.

"Char. Operculum quadricorne margine crenulatum."

"Der Körper des Thieres hat die allgemeine Umrisse des Geschlechtes so weit ich es aus dem verstümmelten Exemplare mit Sicherheit beurtheilen kann. Seine Farben sind ziegelroth und blau-grün. Die Länge ist 5 mm. Der Deckel ist umgekehrt kegelförmig, der obere Theil etwas vorspringend, gerippt. Der Saum ist gezähnt. Die Mitte der Fläche ist etwas vertieft. In der Vertiefung stehen vier kurze, geweihartige Fortsätze. Die Farbe ist roth mit Ausnahme der Rippen welche grün sind. Die Zahl der Kiemen ist bei 20 in jedem Büschel. Der untere Theil ist roth, der obere grün. Der Kragen ist auf der Bauchseite gespalten, etwas umgeschlagen und weiss gesaümt; am Rücken trägt sein oberer Rand mehrere spitzige Fortsätze. Ausser den sechs Borstenbündel des Mantels sind wie bei andern *Serpulaceen* zwei Borstenbündel am Kragen."

"Neu-Süd-Wales." [Schmarda.]

The tube of this species is trigonal, sinuous, white with a blush of pink. In length the animal reaches about $1\frac{1}{4}$ inch, the extreme breadth of the thorax being about $\frac{3}{16}$ths of an inch. The abdomen is more than twice as long as the thorax; the head

and branchiæ slightly exceed the thorax in length. The branchiæ are fifty in number with stout stems and rather short pinnules. They are pink at the base, marked with purple and dark green bands distally. The operculum (pl. XXXII., fig. 9.) with its peduncle is rather longer than the branchiæ, being about a quarter of an inch in total length. The peduncle is dorso-ventrally compressed and becomes gradually broader distally; laterally it is fringed with a pair of delicate wing-like expansions which are prolonged at the distal end of the peduncle into short processes having the appearance of branchiæ, with a row of short processes or pinnules. The operculum proper has the form of an irregular cone with the apex towards the peduncle; it presents on each side a low fold in line with the wings of the peduncle; the dorsal surface is flatter than the ventral and is almost smooth; the latter presents a few low ridges radiating from the apex. The distal surface is nearly transverse, almost circular in outline and slightly concave; it possesses three arborescent appendages attached near its centre and diverging slightly from one another, each dividing dichotomously to form a structure very like the horns of a deer; the terminal offshoots have the form of sharp spines. Very often the three processes arise from a common stem; sometimes there is only an elevation of the distal surface of the operculum and from this the three antler-like processes spring without being directly connected with one another. In colour the operculum presents variously arranged markings of green, crimson and white.

There are seven segments in the thoracic region. The collarette is an exceedingly wide and delicate membrane. The setæ of the first segment of the thorax are very much longer than those of the others. They are very indistinctly feathered on one side towards the apex and taper to a very acute point.

The abdominal setæ (pl. XXXII., fig. 10) are quite unlike those of the thorax. They are geniculate near the apex, the part of the seta in the neighbourhood of the genu being slightly expanded; its concave border ornamented with about twenty minute spinules, the apex extremely fine. The pectines of the

thorax are extremely numerous; in the abdomen they are fewer —there being about seventy to eighty in each segment; they each possess about fifteen teeth, which are nearly all alike in size and shape.

Schmarda's description does not entirely suit the Port Jackson species; but it is more likely that he described an imperfectly preserved variety than that there are two distinct kinds. It is somewhat nearly related to Grube's *Serpula tricornigera* (1) from the Philippines; among other points, however, I think it may be distinguished by the form of the distal surface of the operculum, which in Grube's species is described as having in the centre a depression surrounded by a calcareous ring and having inserted in it a three-sided stem which gives origin to the three antler-like processes. In the form of the setæ and in the rest of the operculum the resemblance between these two forms is very close.

6. Vermilia strigiceps.

Pomatoceros strigiceps, *Mörch.*

Vermilia strigiceps, Quatrefages, tom. cit., p. 521.

"Operculum orbiculare, planum, impressione dilatatâ-deltoideâ in adultis sensim obliteratâ. Testa agglomerata, repens, triquetra. Carina dorsalis compressa, acuta, laciniata, rostrata, basi utrinque serie punctorum impressorum. Latera convexa. Liræ incrementi sæpe laminatæ, confertæ." (Mörch, as quoted by Quatrefages.)

This species, which is unknown to me, is said to occur in the North of Australia and in New Zealand.

7. Vermilia cæspitosa.

[Plate XXXI., fig. 5, and Plate XXXII., figs. 1 and 2.]

Galeolaria cæspitosa, Lamk, Hist. Nat. des An. s. vert., t. V., p. 636; Blainville. Art. Vers, Dict. des Sc. Nat. Atl., pl. I, fig. 4 and 4a.

Vermilia cæspitosa, Quatref. Hist. Nat. des Ann. t. II., p. 531 (1865.)

Serpula (Galeolaria) cæspitosa, Grube, Troschel's Archiv, Band XXI., p. 126, Taf. V., fig. 4 (1855.)

Vermilia insidiosa, Quatrefages, t. cit., p. 532.

Galeolaria decumbens Baird, l.c. Explanation of Plate.

(1) Annulata Semperiana, p. 273, Taf. XV., fig. 7.

This is the Serpula most abundantly distributed on the Coast of New South Wales and Tasmania. It occurs only between tide-marks, most abundantly about midway between high and low water marks, and it is thus exposed daily to the sun for several hours. The effect of this exposure however, is greatly diminished by the thickness of the tubes, and by the massive mode of growth of the species, forming dense and thick aggregations often an inch or more in depth, encrusting rocks, submerged wood, the shells of mussels and similar objects. The ordinary length of the tube is about an inch, but varies according to the age of the individual. It is ordinarily closely cemented down to the object on which it grows, the under surface being expanded and adapting itself to the inequalities of the surfaces to which it is apposed. The lumen of the tube is cylindrical, but the wall is irregularly thickened, the upper surface, which is sharply marked off from the lateral, being marked by a longitudinal groove, narrow in young tubes, broad and shallow in older ones, and produced anteriorly beyond the rest of the tube as a prominent rounded lobe overhanging the orifice. The lateral surfaces do not quite meet the upper at right angles, but slope slightly outwards.

The branchiæ are about 36 in number. They are rather short and stout, tapering towards the apex. They are characterised, as in many other Serpulidæ, by considerable variety in their colouration and markings. The most constant markings are a white band running transversely across the membrane which unites the bases of the stems, a series of white transverse lines or blotches placed at regular intervals along the stems, and, alternating with the latter, a series of parallel pairs of short green or brown longitudinal bands: these green or brown markings are, however, frequently replaced by crimson or purple.

The operculum has a very short peduncle, the distal extremity not extending beyond the ends of the short branchiæ. In shape it may be compared to an inverted cone, flattened to some extent dorso-ventrally, and with a very oblique base directed towards the dorsal side; the dorsal side is marked by a longitudinal groove, bounded by a low fold of the integument; on each side

near the distal end is a prominent triangular flap. The distal surface is oblique, directed towards the dorsal aspect of the animal. It is nearly circular, with a slight bay or indentation in the middle of the dorsal side, and is surrounded by a rim formed by a large number of closely apposed, flattened calcareous spines forming a sort of miniature palisade.

The greater part of the surface is concave and is paved with two or four smooth calcareous plates; towards the dorsal border is a deep pit in which is articulated a large mesial, dorso-ventrally compressed, hollow spine, with a broad base and a rounded apex. Along the dorsal border of the distal surface on either side of this mesial spine is a row of either four, or, more usually, five smaller spines, the size of which increases from the inner towards the outer end of the series. Each, excepting the last (most external), is shaped like an ordinary hand-saw, but tapering towards the extremity, which is slightly curved, and with the teeth few and relatively large; the fourth or fifth (most external) pair, however, have no teeth.

The dorsal setæ are similar to those of *Pomatoceros elaphus*, minutely feathered on one side and with a very fine tapering extremity. The ventral uncini have from twelve to fifteen subequal teeth.

The discrepancies in the descriptions and figures of this species in the memoirs quoted above depend doubtless on their having been for the most part taken from dried specimens. The operculum figured in the paper by Baird quoted above, and described in the explanation of the plate as that of *Galeolaria decumbens*, but not referred to in the text, is the operculum of the present species; the palisade-like structure of the rim has been overlooked.

8. Vermilia rosea.

[Plate, XXXII., figs. 2-5.]

Galeolaria rosea, Val., M.S.
Vermilia rosea, Quatref., l.c., p. 532, pl. XX., figs. 10 and 11.
? *Eupomatus Boltoni*, Baird, l.c., p. 12, pl. II., fig. 10 (1865.)

"Branchiæ breves, cirris 34. Operculum radiatim striatum, spinis medianis, dentiferis cæspitose dispositis. Corpus 130-140 annulis compositum, anterioribus 7. Setæ inferiores subulatæ, incurvatæ. Laminæ crenulatæ. Tubus angulatus, bicarinatus." (Quatrefages.)

This species, characterised by the numerous spines in the operculum is not uncommon in Port Jackson. It is a solitary species, never being found in clusters like *V. cæspitosa*, and always inhabiting a deeper zone. The dorsal setæ are almost identical in form with those of *Pomatoceros*. The pectines are very small; each has from six to nine acute teeth. The branchiæ are marked with bands of red and brown. The operculum is light-red, mottled with brown and dark red. The operculum has a pair of lateral folds with filiform processes as in *Pomatoceros*. This is a larger species than *Vermilia cæspitosa*, being an inch and three-quarters in length.

9. Serpula vasifera. N. sp.

[Plate XXXI., fig. 6, and Plate XXXII., figs. 6-8.]

There are 152 segments in the body of this species. The operculum (pl. XXXII., fig. 6), has a tolerably long cylindrical peduncle; the operculum is vase-shaped with slight dilation where it joins the peduncle; the sides of the vase are formed of about twenty-five ribs, each of which ends at the rim of the vase in a prominent lobe. The distal surface of the vase presents a deep, rounded, central hollow surrounded by a broad margin which is almost transverse to the long axis of the operculum, but slopes slightly upwards towards the lobed margin.

The branchiæ are fifty in number, with stout stems and delicate pinnules. In length they are about equal to the thorax, and extend to a little beyond the extremity of the operculum. The thorax is about one-fourth of the length of the abdomen; it possesses a wide collarette and lateral flaps.

The dorsal setæ of the thorac segments (pl. XXXII., fig. 8), are feathered on one side towards the apex, and taper to a very acute point; the length is about $\frac{1}{16}$th of an inch; there are forty or

so in each thoracic notopodium. The dorsal setæ of the abdomen are long and slender hairs. The pectines, which are about $\frac{1}{250}$th of an inch in length, are about fifteen in number in each segment of the thorax; in the abdomen they are much more numerous; they have four or five teeth, one of which is considerably larger than the others.

In colour the anterior or thoracic region is scarlet, specially bright on the lateral flaps and the collarette. The bases of the branchiæ are crimson; the stems are light green and yellow with narrow longitudinal lines of red and transverse lines of white. The operculum is almost colourless, the peduncle light red, the abdomen reddish.

This species occurs along with *Pomatoceros elaphus*, in Port Jackson.

10. Serpula Jukesii.

Surpula Jukesii, Baird, l.c. p. 20, pl. II., fig. 6.

"Branchiæ in spiram unam convolutæ, lacteæ, filamentis dorso canaliculatis. Operculum et filamentum operculigerum alba. Operculum profunde infundibulatum, multicrenatum. Tubus teres, solidus." (Baird.)

"Seas of Australia." [Brit. Mus.]

It is possible that this may be identical with the Port Jackson species described above, but in the figure of the operculum given in Baird's paper the ribs are much more numerous than in the Port Jackson species. and the description of other parts is insufficient for certain identification.

11. Salmacina australis. N. sp.

[Plate, XXXIII., figs. 7-11.]

This extremely minute species is found in little clusters on the under surfaces of large stones between tide-marks in Port Jackson. The tubes are cylindrical and twisted, intertwining with one another to form tolerably dense masses.

The body of the animal is only about a sixteenth of an inch in total length. The abdominal and thoracic regions of the body are

more nearly equal than is usual in this family, and, when retracted, the former may appear even decidedly shorter than the latter. The branchiæ, which are eight in number, have short stems with two rows of pinnules, and are devoid of terminal dilatations or pseudopercula. The collarette and the lateral flaps are not very greatly developed. The thorax possesses nine segments, of which the first differs from the rest in the form and size of the setæ, and in the absence of ventral pectines. The abdomen possesses nineteen segments with long acicular setæ; the anal segment presents a a pair of very prominent rounded ciliated anal appendages.

The setæ of the first segment are $\frac{1}{75}$th of an inch in length; they are slightly geniculate near the extremity, the genu being armed with a small number of teeth. The remaining thoracic setæ are very obscurely spathulate, being slightly expanded near the fine tapering point. The abdominal setæ are all extremely fine simple hairs, $\frac{1}{250}$th of an inch in length. In the thorax there are 25-32 pectines in each neuropodium; in the abdomen the number is much smaller, diminishing from ten in the anterior region to five in the posterior—the last two or three segments having none at all. The general colour is very light pink, with a number of minute crimson dots on the head.

This species is closely allied to the *Salmacina aedificatrix* of Claparéde, and seems to form a connecting link between it and the *Protula Dysteri* described long ago by Huxley. From the latter it differs in the absence of any pseudopercula or terminal dilatations of the branchiæ; from the former in the form of the thoracic setæ and other minor points.

The slightly spathulate form of the thoracic setæ does not seem to be of sufficient importance to justify a separation of the Australian species from its closely related European allies, though "Setæ spathulatæ vel pectinatæ in abdomine desideratæ" is given by Claparéde (1), as a diagnostic peculiarity of the genus.

I was much interested to observe that the Australian species, like *Salmacina Dysteri*, as first noticed by Huxley, is herma-

(1) Ann. Chét. Supp., p. 154.

phrodite, and multiplies by budding (1). The first indication of the phenomenon of budding is the appearance of a slight constriction about the eighth to the tenth segments of the abdomen. The body behind this now usually developes some additional segments, becomes a little dilated, and the coelom in this region becomes filled with granular cells. A slight elevation now appears on one side of the tenth abdominal segment, and this becomes more and more prominent and divides into eight lobes. Each of these eight lobes becomes elongated, and their bases grow round the circumference of the segment till they come to form a whorl round the body of the animal; soon lateral pinnules appear on them, and they assume the form of branchiæ. A few segments have, meanwhile, been added in front of the bud, and, the oesophagus and gizzard of the bud having become developed from the intestine of the parent, a process of fission separates the bud from the parent organism.

12. Sabella velata. N. sp.

[Plate XXXI., fig. 8, and Plate, XXXIV., figs. 1-4.]

This species has about 40 segments in the body, eight belonging to the thorax. There are eighteen long, slender branchiæ set on a narrow lophophore and forming nearly a complete circle. Connected with the inner face of each half of the lophophore is a filiform process. Connecting together the stems of contiguous branchiæ near their bases are a series of gossamer-like membranes, each four-corned, with two of the corners attached to each of the two stems, the lateral borders being deeply concave and unattached.

The thorax is long and slender and cylindrical; it is composed of eight segments, as in others of the genus. The first segment has but a low ridge representing the collarette of the *Serpulæ*: it possesses a narrow oblique band of dorsal setæ which project but slightly from the surface; they have stout stems and a

(1) Claparéde, "Beobachtungen über Anatomie und Entwickelungsgeschichte wirbelloser Thiere;" "Annelides Chétopodes du Golfe de Naples," p. 437; Huxley, "On a Hermaphrodite and Fissiparous Species of Annelide," Edinburgh New Philosophical Journal, 1864.

broader but short geniculate blade which rapidly tapers to a fine point. Along the outer side of the blade runs a row of minute denticles. The dorsal setæ of the remaining thoracic segments are much more prominent but not very numerous; they are terminated sometimes by short blades which resemble in form those of the first notopodium, but are devoid of the denticles; sometimes by flattened discs. The ventral uncini are very prominent hooklets.

In colour the body is pinkish; the branchiæ light green with narrow longitudinal lines of brown; the membranes between the branchiæ are white.

The tube is of a soft membranous character.

This species occurs with *Serpula vasifera* and *Pomatoceros elaphus* under large stones, etc., in Port Jackson.

13. Sabella punctulata. N. sp.

The general colour of this species is green, due partly to networks of minute pseudohæmal vessels on the surface, partly to the green ova. The dorsal surface is brownish green. The whole surface of the body is ornamented with minute, irregular, rounded spots of a dark crimson, and still smaller dots of greenish white; similar dots occur in pairs at regular intervals along the stems of the branchiæ; the latter are ornamented also with transverse green and brown bands, here and there one of rose-pink, and occasionally one of Naples yellow. There are about fifty branchiæ, and they are devoid of connecting membranes. The collarette is represented by a low fold on the dorsal side stopping short on the ventral side near the parapodia; between the ventral ends of the fold is a deep, longitudinally-directed depression continuous behind with the narrow dorsal groove. The body contains sixty segments. The dorsal setæ are tapering at the extremity and finely feathered on one side near the apex, resembling closely the corresponding structures in *Serpula vasifera*. The ventral uncini are similar to those of the preceding species. The length is nearly an inch.

This species occurs about low-water mark in Port Jackson.

14. Spirographis australiensis. N. sp.

The body of this species is of a general light green colour, slightly tinged with red along the middle dorsal line, a band of blue being external to this. The branchiæ, which are extremely numerous, are ornamented with narrow longitudinal lines of rich brown, the pinnules being almost white with a very faint tinge of green; some of them towards the ventral side have the pinnules lead-colour; the base of the branchial is tinged with brown with narrow longitudinal white lines; the head-lobe is brown; the collarette tinged with brown.

There are eight thoracic and, in a full-sized specimen, about 170 abdominal segments. The low collarette is cleft deeply in the middle ventral line; the ventral lobes have no papillæ. The ventral tentacles are short, slender, and pointed; they are coloured like the stems of the branchiæ. The only representatives of dorsal tentacles are two rounded brown lobes, at the apex of each of which is a pore-like orifice: in a smaller specimen these organs are very much more prominent, and are flattened and leaf-like, resembling those of *Spirographis Spallanzanii*.

The dorsal setæ of the thorax and abdomen are alike; they are scarcely distinguishable from those of *Sabella punctulata*. The uncini are simple hooks on the recurved limb of which are some minute spinules.

The total length of the tube is seven inches; the diameter is about half an inch.

This species occurs about low-water mark on the shores of Port Jackson.

It is possible that the *Sabella grandis* of Baird (l.c., Part II., p. 160), which is described as coming from New Zealand, may be identical with this species, but the description is too inexact to permit of any certainty.

EXPLANATION OF THE PLATES.

Plate 31.

Fig. 1.—Pseudohæmal system of *Eupomatus elegans* from the ventral side enlarged. *a*, ventral vessel; *b*, dilatation of ventral branchial vessel: *c*, common branchial vessel; *d*, head-lobe; *e*, branches of ventral vessel; *f*, plexus in collarette; *g*, plexus in lateral membrane; *n*, tubiparous gland.

Fig. 2.—Anterior relations of the pseudohæmal trunks of *Eupomatus elegans*, seen obliquely from the left side. *v.v.*, ventral vessel; *v.v.*, dilatation of ventral branchial vessel; *d.s.*, dorsal sac; *d.b.v.*, dorsal branchial vessels; *c.b.v.*, common branchial vessel.

Fig. 3.—Body of *Eupomatus elegans*, compressed. *t g.*, tubiparous gland; *h.t.*, contractile dilatation of dorsal vessel.

Fig. 4.—Head of *Eupomatus elegans*.

Fig. 5.—*Vermilia caespitosa*, magnified.

Fig. 6.—Anterior portion of the body of *Serpula vasifera*, magnified.

Fig. 7.—Head of *Pomatoceros elaphus*, magnified.

Fig. 8.—Head of *Sabella velata*, magnified.

Plate 32.

Fig. 1.—Operculum of *Vermilia caespitosa*, ×8.

Fig. 2.—Operculum of *Vermilia rosea*, magnified.

Fig. 3-5.—Spines of the latter, ×44.

Fig. 6.—Operculum of *Serpula vasifera*.

Fig. 7.—Ventral uncinus of *Serpula vasifera*, ×400.

Fig. 8.—Dorsal seta of *Serpula vasifera*, ×325.

Fig. 9.—Operculum of *Pomatoceros elaphus*, magnified.

Fig. 10.—Abdominal dorsal seta of *Pomatoceros elaphus*.

Fig. 11.—Operculum of *Eupomatus elegans*, ×40, slightly compressed.

Fig. 12.—Developing operculum of *Eupomatus elegans*, ×40.

Plate 33.

Fig. 1-2.—Varietal forms of the operculum of *Eupomatus elegans*.

Fig. 3.—Ventral uncinus of *Eupomatus elegans*.

Fig. 4-5.—Dorsal setæ of the first segment of *Eupomatus elegans*, ×400.

Fig. 6.—Dorsal seta of *Eupomatus elegans*, ×400.

Fig. 7.—*Salmacina australis*, ×70.

Fig. 8.—Budding *Salmacina*. *a*, developing branchiæ of bud; *b*, anal appendages; *c*, intestine of parent.

Fig. 9.—Thoracic dorsal seta of *Salmacina australis*, ×400.

Fig. 10.—Abdominal dorsal seta of *Salmacina australis*, ×400.

Fig. 11.—Dorsal seta of first thoracic segment of *Salmacina australis*, ×400.

Plate 34.

Fig. 1.—Dorsal seta of *Sabella velata*, ×325.

Fig. 2.—Dorsal seta of first segment of *Sabella velata*, ×325.

Fig. 3.—Dorsal seta of *Sabella velata*, ×325.

Fig. 4.—Ventral uncinus of *Sabella velata*, ×325.

Fig. 5.—Transverse section of branchial vessel of *Vermilia*; *a.a.*, stalked corpuscles; *b.b.*, free corpuscles.

Fig. 6.—Segmental organ of female *Eupomatus elegans* from the ventral side under slight compression. *a*, external orifice; *b*, clump of ova.

Fig. 7.—Tubiparous gland of *Eupomatus elegans*. *a*, common excretory duct; *b*, sac of the gland.

Fig. 8.—Oblique section of the tubiparous gland of *Eupomatus elegans*, ×400.

Fig. 9.—Transverse section of the same.

Plate 35.

Fig. 1.—Transverse section of the thorax of *Eupomatus elegans*. *t.g.*, tubiparous gland; *n.c.*, nerve cords; *v.v.*, ventral vessel; *d.v.*, dorsal vessel.

Fig. 2.—Transverse section of the thorax of *Pomatoceros elaphus*; letters as in the preceding; *l.v.*, lateral vessels.

Fig. 3.—Transverse section of common duct of tubiparous gland of *Pomatoceros elaphus*, near the external orifice, ×325. *a*, granular epithelium of the interior of the duct; *b*, hypoderm; *c*, cuticle; *d*, pseudohæmal vessel.

Fig. 4.—Epithelium of the tubiparous gland of *Pomatoceros elaphus*, ×325.